FINAL REPORT

MARINE SONOPROBE SURVEY

FOR

INTERNATIONAL PASSAMAQUODDY TIDAL POWER SURVEY

MAINE, U.S.A. - NEW BRUNSWICK, CANADA

by

FAIRCHILD AERIAL SURVEYS, INC.
224 E. Eleventh Street
Los Angeles 15, California

February, 1958

LAUNCHING THE FAIRCHILD ONE

TABLE OF CONTENTS

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PURPOSE OF SURVEY

During the summer months of 1957, a Marine Sonoprobe survey was conducted by Fairchild Aerial Surveys, Inc. to investigate the thickness of sedimentary overburden overlying the bedrock to aid in location and preliminary design of dams and associated structures in the Passamaquoddy Bay region of Maine and New Brunswick. The Marine Sonoprobe, a sonic sounding device, developed by the Magnolia Petroleum Company, was used to perform the survey from a 26' inboard cruiser, the Fairchild One.

The work was performed for the U. S. Army, Corps of Engineers, under Contract No. DA-19-016-CIVENG-57-261, dated 18 March 1957 (Fairchild Project C-22767 EL).

FIELD PERSONNEL

The following personnel were present at Eastport during the field operations:

F. W. Hinrichs, Chief Geologist, in overall charge.
°°H. E. Ohanion, Project-Manager.
Sam Munson, Preliminary Investigation.
°W. B. Huckabay, Consultant.
F. W. Miller, Consultant.
Howard Jackson, Sonoprobe operator.
Gerald Koss, Sonoprobe operator.
°°Gene Oakley, Electro-Fix operator.
Jack Kron, Electro-Fix operator.
Chester Harris, Pilot.
°Gene Sprinkel, Boatman.
George Mitchell, Supply Boat Captain.
Raymond Creamer, Electro-Fix Station Attendant.
Harry Logan, Electro-Fix Station Attendant.

° Scientific Service Laboratories, Inc., Dallas, Texas.
°° Moran Instrument Corporation, Pasadena, California.

GENERAL OUTLINE OF FIELD PROCEDURES

Shortly after the contract was signed in March, Mr. Munson, the Fairchild Electro-Fix representative, proceeded to the project site to make a preliminary survey of the possible Electro-Fix Beacon Station sites, launching site, and so forth. On the basis of the data collected from this reconnaissance, the survey was planned in detail. The best locations for the beacon stations were determined and visited so that upon the arrival of the equipment they could be put into use immediately.

Upon arrival of the equipment and boat, calibration and accuracy tests of the positioning equipment were carried out and tests of the Marine Sonoprobe were carried out. Upon satisfactory operation of both systems, actual production began on June 13th and lasted until July 27th with a total of 96.7 linear miles of survey lines completed.

Eleven individual areas were surveyed in the Passamaquoddy Bay region, lettered from A through L (excepting I). The general location of these areas with respect to Passamaquoddy Bay and adjacent bays may be seen in figure 1. The areas indicated were surveyed by the boat, proceeding along parallel lines separated by a distance of 300 feet. A Marine Sonoprobe record was made as the boat proceeded along each line, closely following its pre-determined course with the aid of the electronic positioning system which, in addition, recorded the exact course followed.

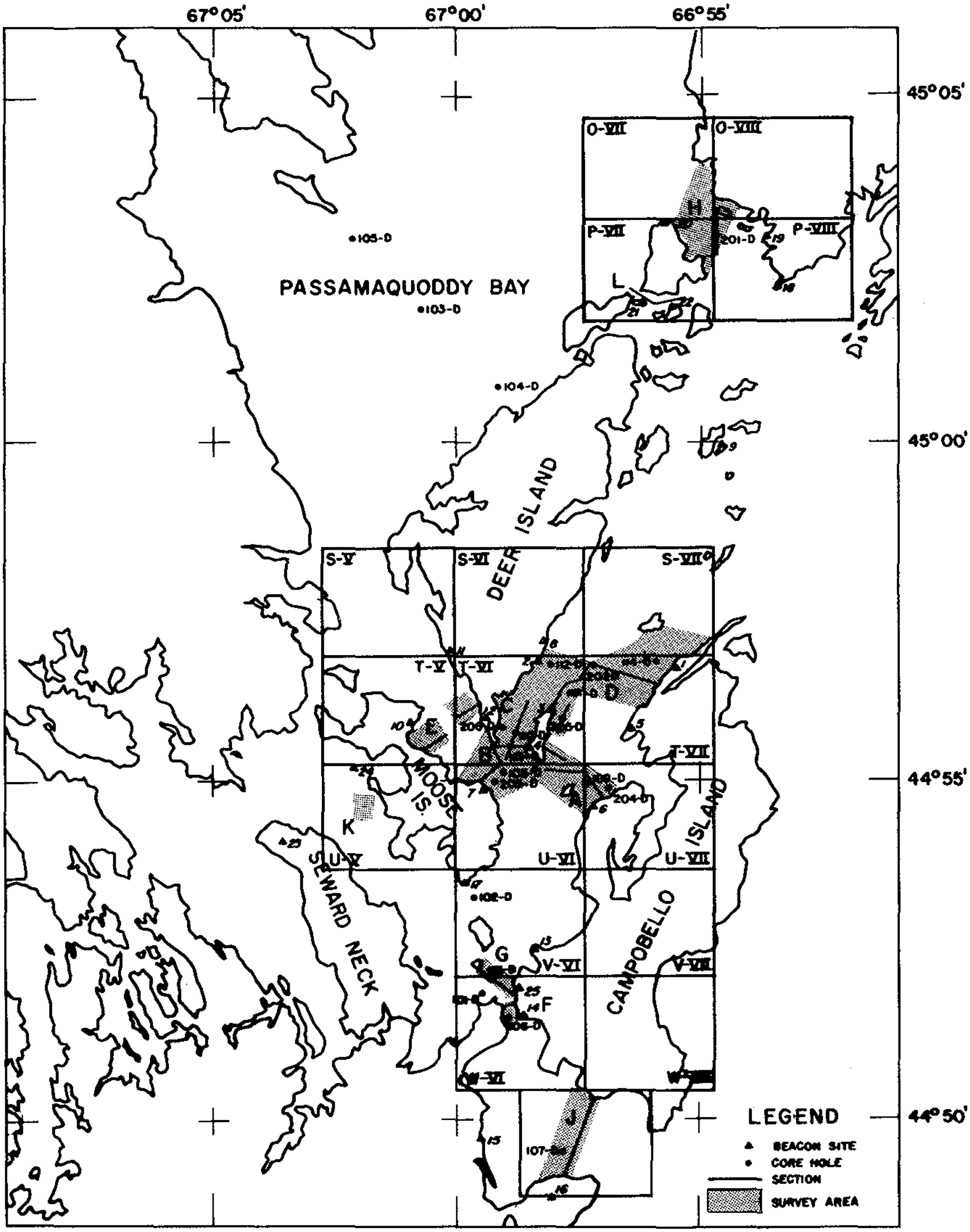
Upon completion of the field work, the compilation of data was carried out in Fairchild's Los Angeles office.

THE SURVEY BOAT

The Fairchild One, a 26 foot inboard cruiser with an 8 foot beam, was brought to Eastport, Maine by truck and trailer (see frontispiece). The boat has a three-foot draft and is capable of a speed of about 10 knots. The launching site was at the concrete seaplane ramp conveniently located just north of Eastport.

In addition to the Fairchild One, a second boat was used to carry personnel, equipment, and supplies to the various shore stations throughout the area.

The Fairchild One carries ample power supplies to run the electrical and electronic equipment installed in the



MARINE SONOPROBE SURVEY
PASSAMAQUODDY BAY, MAINE & NEW BRUNSWICK

0 1 2 3 4

SCALE IN MILES

Compiled by FAIRCHILD AERIAL SURVEYS, INC. Los Angeles — New York

DRAWING NO. 947

limited space. The boat is also outfitted with fire-fighting and fire prevention equipment, including a large CO_2 cylinder, two portable CO_2 extinguishers, carburetor flame arrestor, and vapor-proof exhaust fans, as well as 3 electric or mechanical pumps, a hand bilge pump, life jackets and a life raft.

The problem of safe navigation of the boat was complicated by several unusual conditions other than those of fog, wind, and waves. The tidal range of about 25 feet creates tidal currents through the narrow entrances as swift as 7 knots, and in certain areas whirlpools dangerous to small craft. The work in some of these areas had to be scheduled during periods of slack water when the currents were not so swift.

THE MARINE SONOPROBE

The Marine Sonoprobe is a geophysical instrument working on the seismic principle whereby a sound generated in the boat travels through the water to the ocean bottom. A part of this sound energy is reflected by the bottom and by each sedimentary bed and by the bedrock in proportion to the contrast of acoustic properties at the successive interfaces. Most seismic instruments use an explosion as a sound source; however, the Marine Sonoprobe sound source is a pulsed vibrator which has certain distinct advantages.

1) The sound can be beamed toward the bottom (50% of the sound energy is confined in a cone of 30° solid angle).

2) The frequency and shape of the outgoing signal can be varied. (The fundamental frequency of the sound generated is about 4000 cycles per second.)

3) A rapid sequence of high energy pulses of short duration is sent out, making possible a continuous record of the sound reflections. (12 pulses per second are transmitted to the water with pulse lengths of about 1 cycle at the fundamental frequency.)

These advantages become doubly apparent where, in a difficult survey area such as Passamaquoddy Bay, the underwater topography is rugged, with steep canyons, rocky areas, and small pockets of various types of sediments. The sound is beamed downward in narrow canyons without excessive side echos, whereas, with customary seismic methods utilizing explosive charges, the energy is reflected equally well from reflecting surfaces in any direction and at any depth, and the recorded results would be exceedingly complex and inconclusive.

The reflected sound is detected between frequencies of about 900 and 9,000 cycles per second and is recorded on a continuously moving Teledeltos electro-sensitive paper and can be viewed on one of two cathode ray oscilloscopes. The viewing oscilloscope aids the Marine Sonoprobe operator in the proper adjustment of the instrument, and the second oscilloscope is photographed by a camera with 70mm film to make a permanent record of the oscilloscope reading. The oscilloscope photo for Fiducial 97, line J4, is shown as an inset on figure 3.

The end result is a profile of the bottom and the beds immediately beneath the bottom where the differences in acoustic properties have reflected the sound back to the boat.

The instrument, developed by the Magnolia Petroleum Company, consists of a precision power supply unit, a pulsing unit which generates the power for electric pulse, a magnetostrictive transmitting transducer which converts the electrical energy into acoustic energy and beams it downward, a receiving transducer which receives the reflected energy, a unit which amplifies the signals received by the receiving transducer and presents them simultaneously on the recorder and the oscilloscopes. The pulsing unit is capable of applying approximately one million watts of energy to each pulse. This amount of power somewhat more than saturates the transmitting transducer and usually some slightly lower power setting is used which is sufficient to saturate the transducer and eliminate any possible cavitation as these are the practical maximum electrical and mechanical limits of the system.

The returning signal, before recording, is filtered through high-pass and low-pass filter. The filters allow any portion of the spectrum to be recorded from 900 cycles to 9,000 cycles per second. Different geological situations, for best recordings, may require somewhat different filter settings. The filter settings were normally not varied during the course of any one area, but were left fixed. The filter settings used on the Passamaquoddy Bay job allowed a spectrum to be recorded between about 2,000 and 9,000 cycles per second.

On the face of the oscilloscopes are shown a group of ten lines, each representing a ten-foot segment, making up the first 100 feet of depth (see the inset on figure 3). On these lines are superimposed the wave forms of the returning energy. Indicated on the photo are the following: 1. fiducial number, 2. data card, 3. clock, 4. initial or outgoing pulse - depth 0 feet, 5. energy reflected from bottom - depth 37 feet, 6. first multiple of bottom reflection - depth 77 feet, 7. energy reflected from bedrock - depth 93 feet. Occasionally when the depth reaches about 75 to 100 feet and sub-bottom reflections are observed to be returning from depths greater than 100 feet, it is convenient to switch over the oscilloscope to the 100 to 200 foot depth range. In this way, the complete set of waves can be examined. Occasionally, two oscilloscope photos were made at the same location to record both depth ranges.

THE RECORD

The Marine Sonoprobe records are made on Teledeltos chart paper (manufacturer's number 57663), which is a lead azide paper sensitive to electrical sparks. The chart paper is 10 inches in width, the top margin representing the water surface, and the bottom margin representing a depth of 200 feet. Horizontal lines are ruled across the paper delineating 10 foot intervals. In areas where water or sediments are deeper than 200 feet, the record shows the interval between 200 and 400 feet. As the trace goes off the bottom of the chart, it simultaneously appears again at the top edge of the paper and continues down, the top edge of the chart then becoming the 200 foot level. Figure 3, line B17, shows a canyon 350 feet deep with the trace for the deeper part being on the 200 foot to 400 foot interval.

The original records have been handled with extreme care, and in order to preserve them, all interpretative notations have been made on photostat copies. It is suggested that the original records be carefully stored flat or in rolls for in this way they will remain useful for an indefinite period of time.

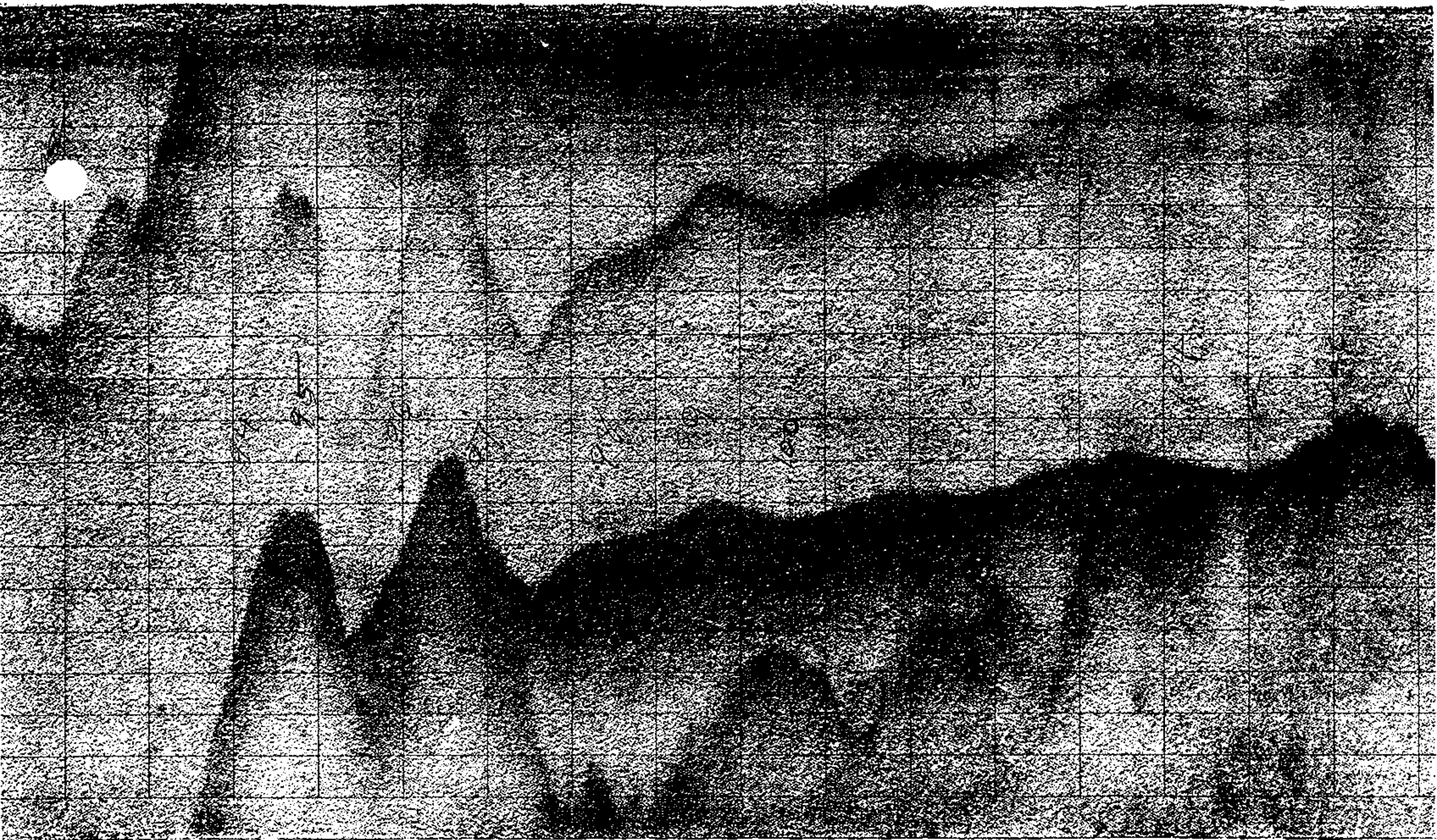
INTERPRETATION OF REFLECTIONS

On the records will be found 4 distinct types of reflections:

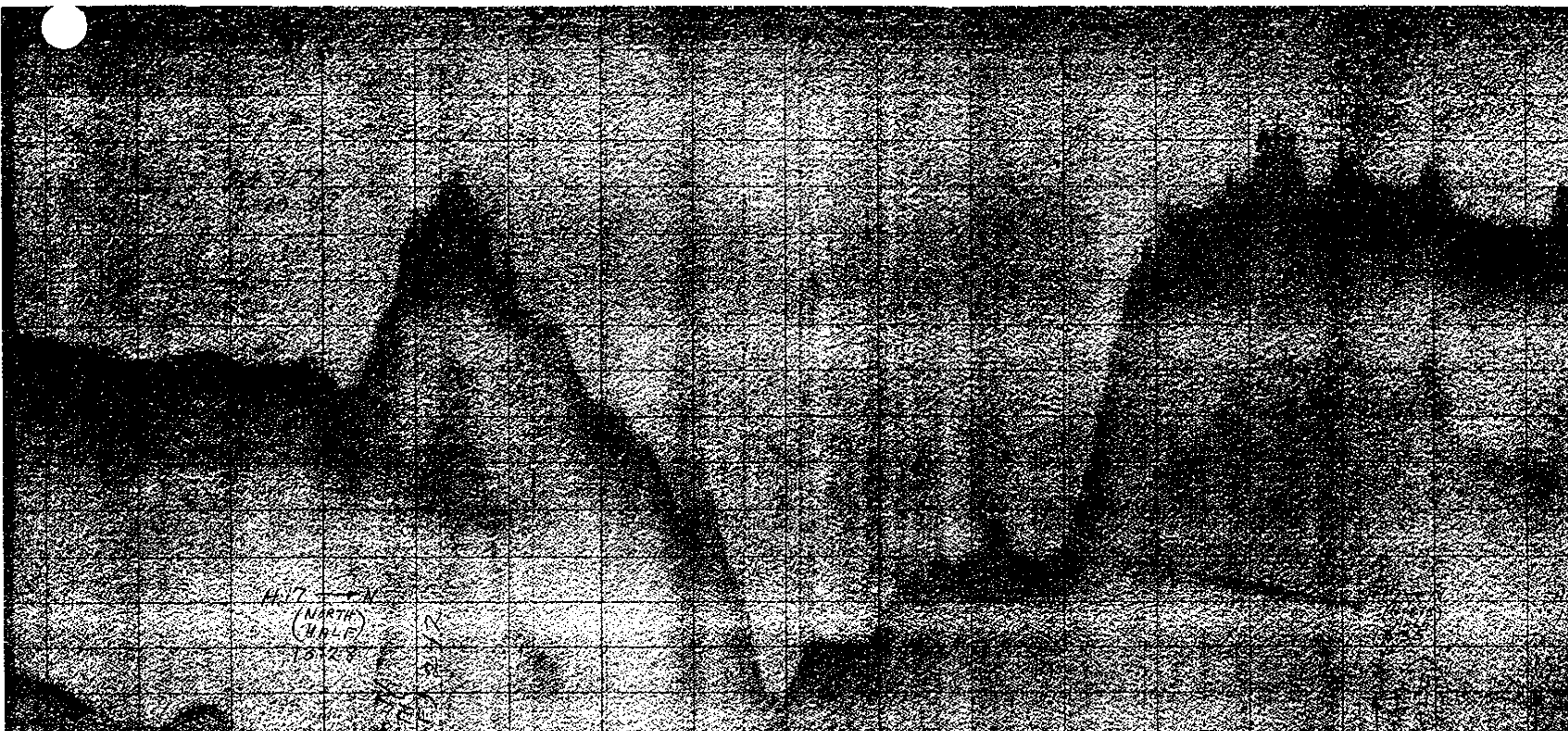
1) Cross-talk. From the surface to the first 10 or 20 feet of depth will be found a darkened portion of the record, representing the direct detection of the transmitter energy by the receiving transducer. This is not bothersome, except in cases where surveying in very shallow water or in areas having depths between 200 and 220 feet.

2) Multiple Reflections. When an underwater sound is produced, a certain portion of this sound may be reflected back and forth between the surface and the bottom. If "X" time is required for the sound to be transmitted from the boat to the bottom and return, then 2 "X" time will be required to receive the first multiple, which goes from the boat to the bottom and is reflected back to the water surface to the bottom and to the boat again. This produces a similar but fainter curve at twice the depth and with twice the relief of the original reflection. At times, a second and third multiple may be observed.

FIG. 2



D12 X 2



H17

3) Side Reflections. About half the sound generated is directed downward in a beam with a 30° solid angle, the remainder being distributed throughout the water. In some areas of rough bottom, side reflections are recorded, and a detailed examination of the nearby topography is necessary to distinguish the side reflections from bottom or sub-bottom reflections. These side reflections can occur either as ghost images or ghost interfaces, depending on whether they appear above or below the level of the bottom.

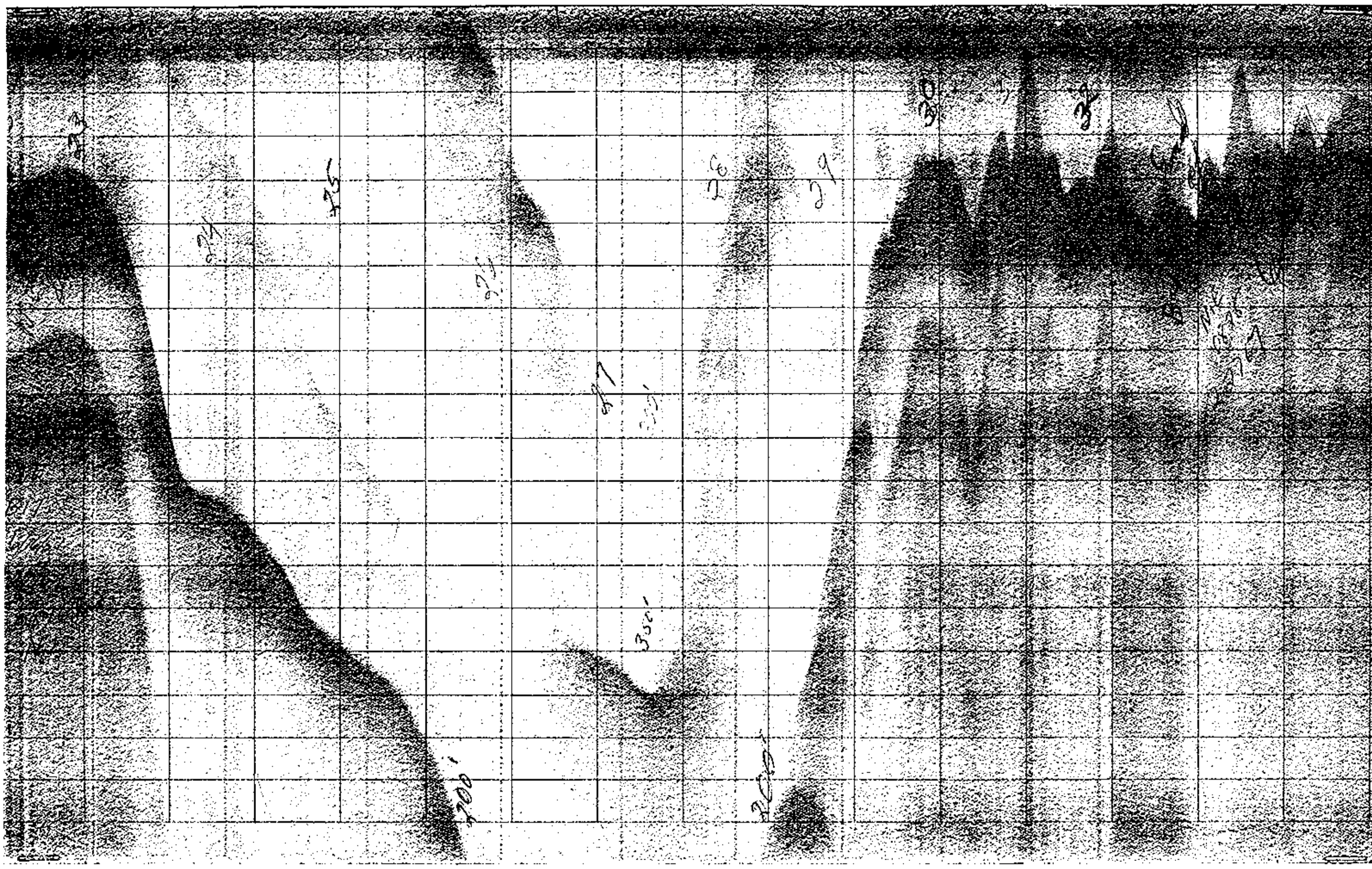
4) Bottom Reflections. On nearly every line in the survey, the bottom reflections are very plainly seen, the only exception being where bottom slopes steeper than about 40° are encountered. This is due to the acoustic energy being reflected off to the side rather than back up to the boat.

Some very shallow areas of sedimentary cover possibly have been overlooked since in the attempt to record deeper, more important features, the sensitivity (gain) of the instrument was kept at a high level, making a dark bottom reflection about 10 feet in width.

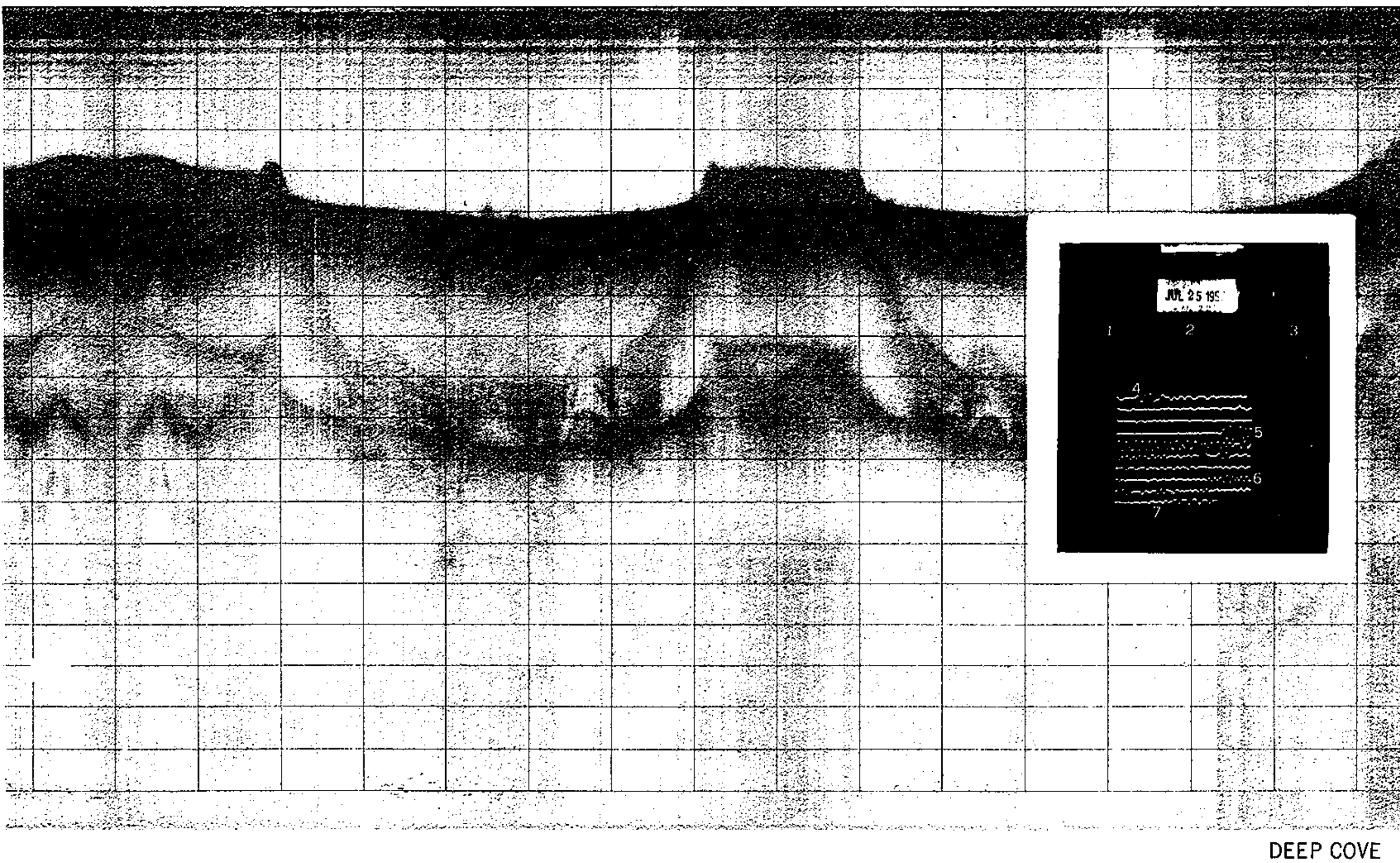
When the bottom topography becomes so rough that some point not directly beneath the boat is closer to the boat than the bottom itself, then the distance to the closest point may be indicated on the record as the distance to the bottom. This effect is somewhat modified by the beaming of the energy by the transducers. However, many of these features still appear as ghost images, or side reflections as discussed in item 3 above. It is suggested that in critical areas, where submarine canyons are very steep sided, sufficient vertical wire soundings be made to ascertain the precise depth of the canyon.

5) Bedrock Reflections. Securing reflections from the bedrock below the bottom is considerably more difficult than securing those from the bottom itself. This is due to several reasons, but primarily due to the difficulty of finding as good a reflection coefficient between the sediments and bedrock as occurs between the water and the bottom.

The known bedrock types in Passamaquoddy Bay are variable, including basalts, conglomerates, limestones, and shales. These rock types vary considerably in their acoustic properties. The sediments of the area likewise are variable, ranging from fine, clay-like materials to sand, to gravel and massive boulders.



B 17



DEEP COVE

Typical acoustic contrasts are shown in item A below, first of a list of the various factors affecting the bedrock reflections:

A) <u>Acoustic Impedance Contrast</u>: In order to be able to record a reflection arising from a contact between two different rock layers, there must be a contrast in the acoustic properties of the two rock types.

This is termed "acoustic impedance contrast", and, for detection and recording, should be perhaps 10% or more. All of the factors which produce differences in acoustic impedance are not completely known, but differences in velocity of sound and the density (caused usually by change in lithology) are the most important.

For approximate determination of the probability of a reflection at an interface, we can use the simple formula:

$$\% \text{ of energy reflected} = \frac{R_1 - R_2}{R_2 + R_2}$$

where R=V (velocity) x D (density)

A reflection should be detectable when 10% or more of the energy is reflected (providing this amount of energy, upon return to the receiver and recorder, exceeds the normal signal-noise ratio).

Thus, for clay overlying basalt, a good reflection would occur.

	CLAY	BASALT	
(V)	4000	12,000	$\% \text{ reflected} = \frac{36{,}000 - 7000}{36{,}000 + 7000}$
(D)	1.75	3	
(R)	7000	36,000	$= \frac{29}{43} = 67\%$

On the other hand, there may be little or no opportunity for reflection:

	GLACIAL DRIFT	SHALE	
(V)	5500	6000	$\% \text{ reflected} = \frac{14{,}400 - 13{,}200}{14{,}400 + 13{,}200}$
(D)	2.4	2.4	
(R)	13,200	14,000	$= \frac{1200}{27{,}600} = 4\%$

By coincidence, then, very different rock types have a combination of qualities which combine to make their contact undistinguishable.

B) Nature of the Interface: A sharp contrast in lithology would be most favorable for a good reflection; gradational changes in lithology would probably result in gradational changes in acoustic qualities, which could not be easily seen as reflections. Similarly, smooth interfaces would be more readily recorded than very irregular ones.

C) Attitude of the Interface: About 50% of the acoustic energy of the Marine Sonoprobe is contained in a vertical cone with a solid angle of 30°. Thus, some energy is escaping to the sides and perhaps even a little is traveling horizontally. Obviously, the best reflections will result when the interfaces are horizontal. As the dip of the interface increases, the main portion of the reflected energy is directed away from the boat, until (theoretically, if it were perfectly beamed) no energy would be returned to the water surface from an interface with a 45° or greater dip. In practice, good interfaces may be detected (because of the side energy) at greater angles, but this can be regarded as a definite limit of this or any acoustic system.

D) Distance of Interface Below the Instrument: In depths of water up to 300 feet or so, this is not too critical, although obviously in shallow water more energy per unit area penetrates into the bottom. The depth of the reflecting interface under the bottom is most important. (This bears upon the common phrase "depth of penetration", which is perhaps too freely used without consideration of the probability that there may be no interfaces in the bottom capable of producing detectable reflections - the energy may be "penetrating" to great depths.) Examples of the degradation of the reflection with depth are visible virtually everywhere where sub-bottom reflections occur. In general, the disappearance of a reflection may be caused by one or a combination of the following factors:

1) Progressive absorption of the descending and returning sound energy.

2) Interface passing under a strongly reflecting layer.

3) Steepening of the interface.

4) Confusion with a multiple reflection or cross-talk.

In summary, then, the Marine Sonoprobe will detect interfaces with sufficiently high reflection coefficients, which are not dipping too steeply, down to some depth determined by local conditions.

ELECTRONIC POSITIONING

Positioning of the survey boat was accomplished by Fairchild's Electro-Fix Division, using electronic distance measuring equipment provided by the Moran Instrument Corporation of Pasadena, California. The use of this system requires three electronic installations, one on the boat and two at known positions on land overlooking the survey area.

A signal is sent from the master station on the boat at a frequency of 462 megacycles. This signal is received by the beacon stations on land which each re-transmits a return signal at a frequency of 395 megacycles. The time for the signal to travel at the speed of light from the boat to each beacon station and to return to the boat is measured very precisely. This time is expressed on a cathode ray tube located in the boat. The reading is made by measuring the angular distance between a reference pip and the return signal pip. The reference pip is made by the outgoing signal and is permanently located at the 12 o'clock position. The return pip is free to travel around the circumference of the cathode ray tube, thus indicating the distance to the ground station. Two distance scales are available, one revolution indicating a distance of either 50,000 feet or 5,000 feet. The readings are normally made to the nearest 5 feet.

Electronic positioning transmissions are of ultra-high frequency. Therefore, only line-of-sight transmission is possible and the range of transmission is limited by the curvature of the earth and by ground obstruction.

In order to form strong trigonometric intersections, the angle formed at the boat between the ground stations must be considered; these angles had to be taken into consideration in the placement of the ground stations. The ground station sites were located so that nearly all the trigonometric intersections fall in the range between 60° and 120°, the range of most accurate intersection.

AUTOMATIC POSITION TRACKER

An automatic position tracker, whose function it was to keep the boat on its prescribed course during the survey, was combined with the electronic distance measuring equipment. The positions of the shore stations and the pre-determined survey lines were plotted on a map which was placed on the automatic tracker table. A device called a metering head was centered precisely on the map location of each ground station. The distances from each shore station to the boat were continuously measured by the equipment operator, and the movement of the distance cranks to the shore stations was mechanically transmitted to gears in the metering heads which drove long invar steel worm gears intersecting in a stylus which indicated the position of the boat. As the boat proceeded along the survey line, its exact position could be seen at any moment on the tracker and, if the indicated position was off the survey line, it could be corrected by appropriate adjustment of speed and direction of the boat.

At intervals of approximately 350 feet along each line, a numbered fiducial mark was placed on the map showing the position of the boat at that instant and a fix button was pressed which electrically scribed a corresponding mark across the Marine Sonoprobe record.

In addition, the distances in feet to each shore station beacon were recorded in the electro-fix report. After the survey, the identical tracker was used in the laboratory in Los Angeles to re-plot the lines at the compilation scale of 1"=400 feet (1:4800).

The automatic position tracker was very helpful in keeping the boat on course. Figure 4 shows a series of profiles in area H where the currents were particularly troublesome. The profiles were at right angles to the current, but in spite of this, the boat was able to follow its prescribed courses very satisfactorily.

ACCURACY OF POSITIONING

Several calibrations and checks of the Electro-Fix equipment were made before and during the course of the survey to insure its accuracy.

Calibration tests: The calibration tests were conducted over a known distance by taking the master stations to one known point and the beacon stations to the other. Eight beacon stations were checked over a known distance to ± 5 feet. Also each of two master stations were checked against each of 6 beacon stations over a known distance of 9770.3 feet to an agreement of ± 5 feet.

Daily tests: The boat usually occupied a known position before each day's production. At this position, the equipment was checked to insure that the proper distances were read.

In addition, several tests were made measuring the distances between various control points.

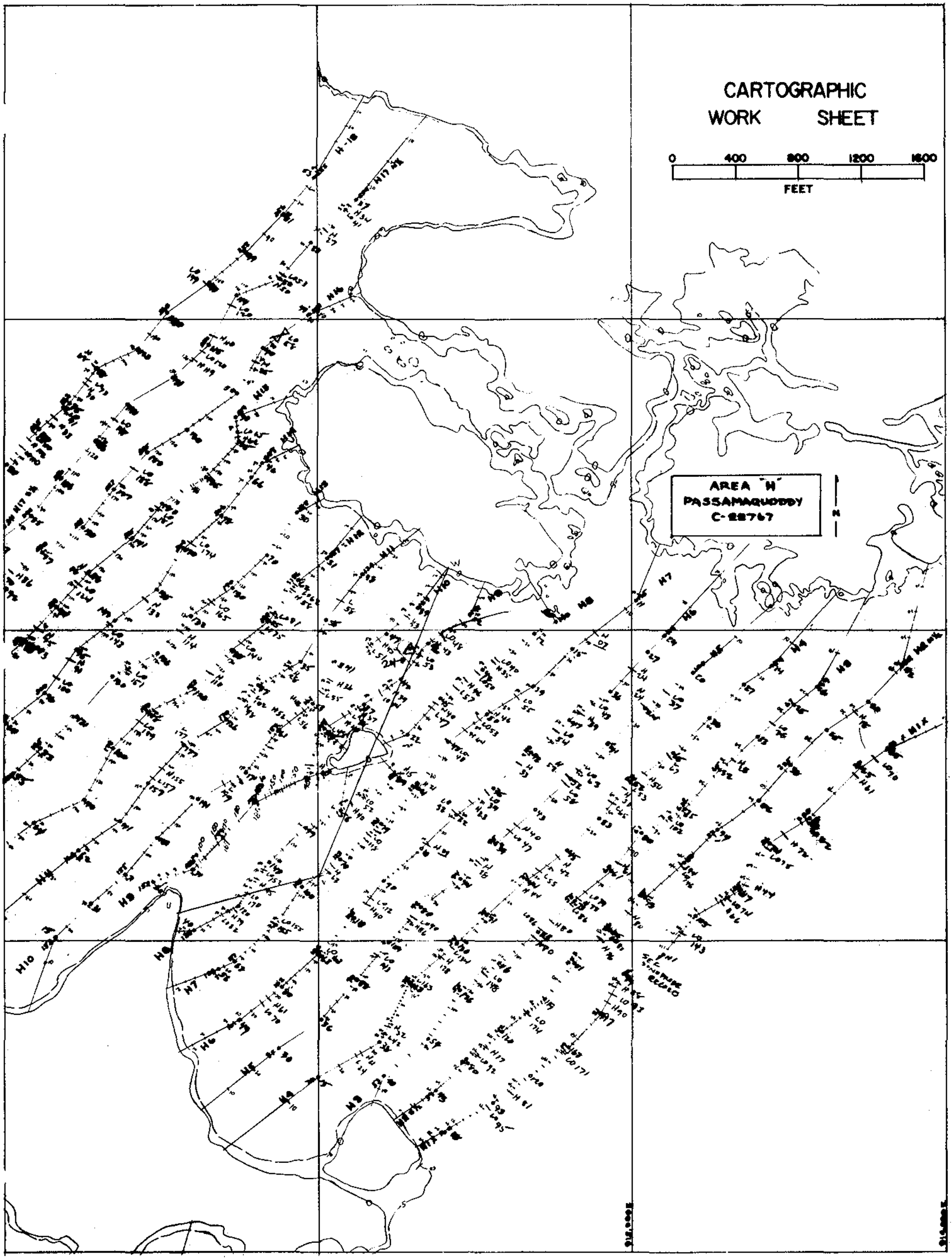
Typical examples of this test are:

STATIONS	COMPUTED DISTANCE	ELECTRO-FIX DIFFERENCE
Cable to Chocolate	8,369.97'	+ 3.0'
Cable to Kendall 2	10,575.0'	- 1.0'
Kendall 2 to Chocolate	12,953.7'	+13.7'
Kendall 2 to Eastport R.M.	9,093.8'	-13.8'
Deer R.M. to Chocolate	8,798.3'	-12.7'
Deer R.M. to Kendall 2	7,788.9'	- 9.1'

As an acceptance test, two underway runs were made for comparison of the Moran positioning and customary two and three transit fixes from shore. The client indicated that a maximum horizontal difference of 48 feet was detected between these methods. It is felt that most of the fiducials are located to within ± 25 feet with a probable maximum error of ± 50 feet.

Areas F, K, and L were not positioned by electronic methods, but were positioned by visual triangulation methods by Corps of Engineers' personnel. From known positions on shore, angles to the survey boat were taken at the instant a visual flag signal was made on the boat. At the same time the flag signal was made, the Sonoprobe records were marked and numbered in the usual manner. A plot was then made by the Corps of Engineers showing the location of the boat with the fiducial numbers, and Fairchild was presented this data in the form of the distances from the shore stations to each fiducial position occupied by the boat. Fairchild then plotted the data in the same way as the Electro-Fix data.

FIG. 4



CARTOGRAPHIC
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THE DATA NUMBERING SYSTEM

Letters A, B, C, D, E, F, G, H, J, and L represent the work areas. All survey line numbers are preceded by one of the above letters, for example, A9 being line 9 in Area A. Re-runs are designated by an X following the line number, for example, A9X. A number following the X indicates the number of times the line has been re-run, A9X2. The general direction that the line was run is indicated on the record by an arrow preceding a compass direction. A line marked E was run eastbound from west to east. When a line is followed by an east half or west half designation, it means that, for some reason, the line was run in two parts. Figures 2 and 3 show the manner in which the profiles were numbered.

The date and time of beginning and ending of each line was marked on each profile to facilitate the addition of the mean sea level data from the tide curves. Data regarding each line was entered in the Sonoprobe operator's report.

Occasionally, extra fiducials were made for one of two reasons:

1. To obtain an oscilloscope photo where one electro-fix station was temporarily blanked out. This was called a "photo fix".

2. To get an extra oscilloscope photo to see the next lower hundred foot interval of depth (as the oscilloscope presentation is limited to any selected 100 foot depth increment, and any interval may be photographed and seen by switching.)

DATA PRESENTED

The raw data consists of the Marine Sonoprobe records, the Sonoprobe Operator's report, the Electro-Fix report, the oscilloscope film (negatives), and the tide curves.

This data compiled into the form of submarine contour maps shows the depths below mean sea level of the bottom and bedrock. In addition to the delivery of these maps, records and reports, one full-scale photostatic copy of each acceptable Marine Sonoprobe record on which interpretational work has been plotted is presented. Finally, the various work sheets on which the compilation processes were carried out are presented.

COMPILATION OF MAPS

Positioning, contouring, and interpretation of the data was done in the Los Angeles office.

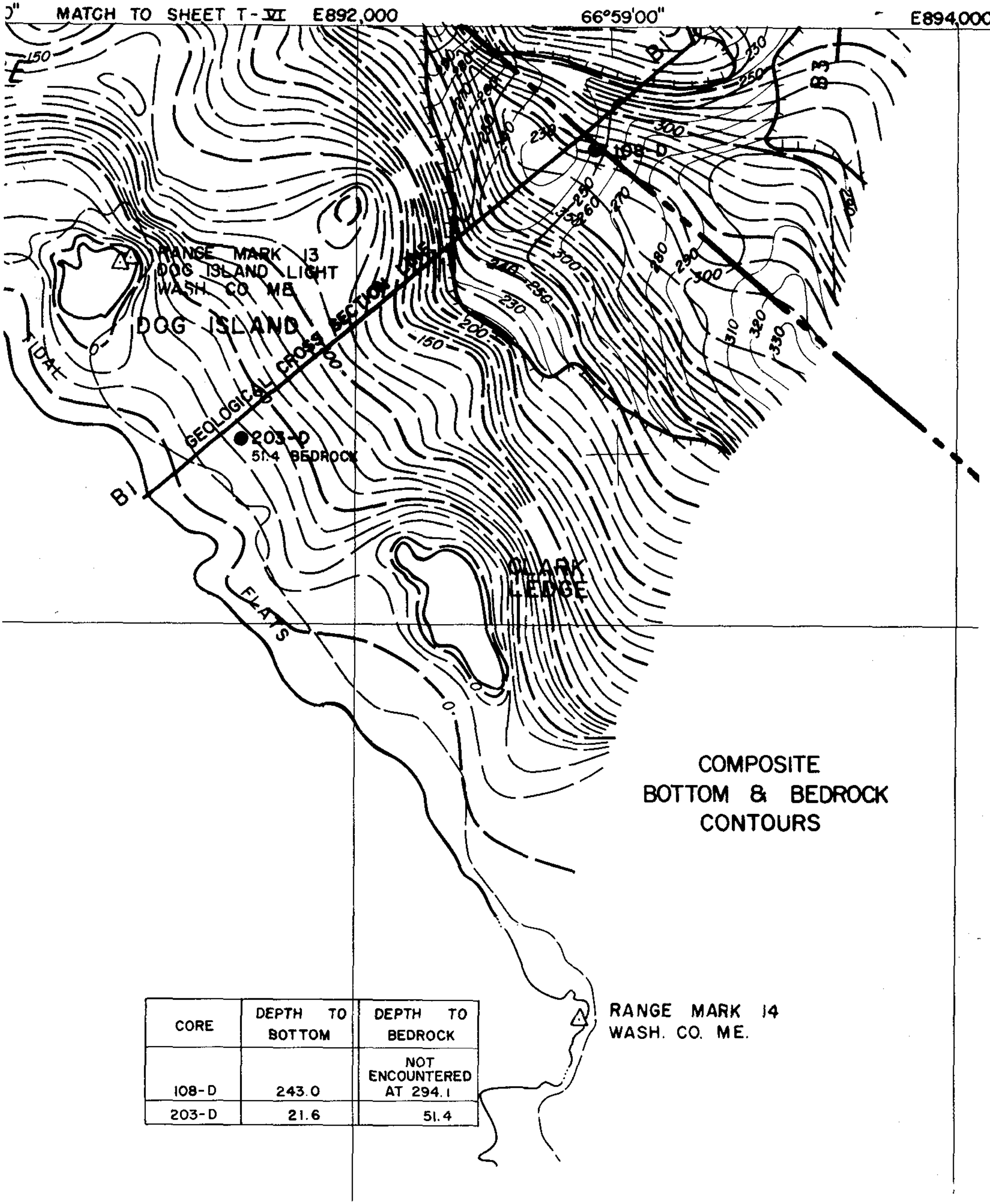
Positioning: Using the same automatic position tracker mechanism, the distance from each beacon station to the master station on the boat was plotted at a scale of 1 inch = 400 feet. All positions were based on the Maine Coordinate System, East Zone, which appears on the Corps of Engineers base maps. For areas falling outside of these maps (areas J and K), this system was extended to include the new map sheets.

Contouring: The depths to bottom and bedrock were determined from the Marine Sonoprobe records. A datum line thirty feet below mean sea level was first drawn using the date and time information on the record itself and the tide curves furnished by the Corps of Engineers. At the minus thirty foot level, this datum line remains on the record in spite of the large variation in tide level. Draft corrections were made on the Marine Sonoprobe instrument so that the top margin of the record always represents the water level. The velocity of sound in the sea water at the survey area was very close to the calibrated 4,800 feet per second and the depths were read directly from the records without further correction.

Depths to the bottom were first plotted and contours drawn. This was done by entering the depths from the Sonoprobe records on the position plot and connecting all points of 10 foot depth intervals with contour lines. The shore line from the Corps of Engineers base maps was used to aid in the forming of the contours, especially in the areas between the ends of lines and shore. Notations on area H can be seen in figure 4.

Depths to Bedrock were determined only after considerable study of the original records. The degree of certainty which could be established for the overburden-bedrock contact was highly variable, for the many reasons discussed under "Interpretation of Reflections". For this reason, reflections were graded by record quality as either certain, probable, or speculative. For example, a clearly defined dipping reflection might be coded as "certain" for the first 40 feet, "probable" for another 20 feet, and "speculative" beyond that. On the photostatic copies used for interpretational markings, these grades of certainty were shown by solid, dashed, and dotted lines, respectively. A color code showed the bottom profile in black, bedrock (in areas of overburden) in red, and any intermediate overburden layers in purple. Prior to making the final conclusions which were to be embodied in the final contour maps,

FIG. 5



COMPOSITE
BOTTOM & BEDROCK
CONTOURS

CORE	DEPTH TO BOTTOM	DEPTH TO BEDROCK
108-D	243.0	NOT ENCOUNTERED AT 294.1
203-D	21.6	51.4

each original record was studied in relation to adjacent records and to certain core-hole data provided by the Corps of Engineers. These conclusions in certain areas were combined with geologic probability in order to present the contoured data. In order to know the probable degree of reliability of the contoured maps in any area, the original and photostatic records should be reviewed as a part of the study.

Three Final Maps were made. On the Corps of Engineers base map were drawn the bottom contours and on an overlay to this map were drawn the bedrock contours. The third map was made by photographically reproducing the first two superimposed, the areas were bedrock outcrops on the bottom being indicated by a single contour system and areas of overburden by both systems (Figure 5). To distinguish the two systems, the bedrock contours are heavy dashed lines and bottom contours are light solid lines. In addition, areas where bedrock outcrops on the bottom are enclosed by a hachured line.

The locations of the Corps of Engineers core holes are indicated and numbered on the final map sheets as well as the sites of the Electro-Fix beacon stations located on shore. Geologic sections are shown by heavy lines.

DISCUSSION OF RESULTS BY AREA

AREA A. Area A lies at the north end of Friar Roads between Indian and Campobello Islands. The areas of overburden in this area fall into two classes, certain and speculative. The large area in the channel is speculative because there is not much indication on the records of sediments. There are no definite reflections from a bedrock-sediment interface; however, core 109-D indicates 50 feet of sands, gravels, and cobbles. Using the core data as a starting point, the overburden has been delineated by the change in slope near the canyon bottom.

In contrast, a well-defined area of overburden is shown on each side of the channel.

AREA B. This is one of the larger areas located at the south end of the Western Passage. Running in the narrows between Dog Island and Deer Point is a submarine canyon more than 380 feet deep (see figure 3, line B17). This canyon apparently is swept clean by the swift tidal currents. Farther to the southeast where the channel is wider, the canyon bottom is filled with overburden. This area is delineated by the records and the type of sediments shown by core 108-D.

The areas with overburden near the boundary of area B are discussed with Area C.

AREA C. This area is located in the Indian River channel between Deer Island and Indian Island. A large portion of the canyon is filled with sediments to the north of the bedrock ledge between Deer Point and Indian Island. Core 110-D, in the same area indicates about 48 feet of sediments, predominantly clay, overlying coarser sediments to a depth of 103 feet. The top of the coarser sediments is recorded but not the bottom of the canyon. The deeper parts of the canyon are contoured on the basis of the core 110-D, the shapes of the sides of the canyon where they are free of sediments, and this interface extending beneath the softer sediments. This sedimentary layer extends northward almost to the end of Indian Island where the canyon is apparently swept free of sediments again.

AREA D. This is the largest of the survey areas. It covers an area between Deer and Campobello Islands extending from Area B northward to Casco Island.

North of Indian Island. A large area of overburden extends from Indian Point northward to Core 112-D. These sediments are as thick as 50 feet.

To the west of Indian Island is another large area of overburden with more than 100 feet of thickness (see figure 2, line D12x2). This and the area described above are very well defined with good reflections from the bedrock. A second pair of sedimentary areas lie to the north of these and are shown on lines C19 through C22.

The bedrock area northward from Core #112-D and extending between the overburden areas last mentioned above has some different reflection characteristics. If this falls in a critical area, it is suggested that further investigation be initiated to prove whether the area is bedrock or some acoustically inpenetratable sedimentary cover.

Three more large areas of sedimentary overburden occur to the east, west and south of Green Island. These are well defined, especially the area to the west of Green Island, which has a great thickness of sediments defined by good reflections.

Except for a few small pockets of sediments, the one remaining overburden area lies in the main channel just to the west of Campobello Island. The channel deepens to the north to 370 feet from its 290 foot depth at the south end. Several linear bedrock features are apparent in the northern third of the channel. Although many of the deeper interfaces are classified as speculative, a sufficient number of good reflections were obtained to make it possible to draw the speculative portions reasonably accurately.

AREA E. Area E was surveyed in two parts, on either side of the Western Passage, the main southern entrance to Passamaquoddy Bay.

The south-west portion lies against Moose Island involving lines E1 through E6. Lines E2 through E6 revealed 2 moderately well-defined areas of overburden, the first lying on the upper slope down to a depth of about 70 feet. Further down the slope below the bedrock ridge lies another thicker deposit of sediments.

On the north-east side of the Western Passage, an area of overburden is found on the upper slope.

AREA F. Only poor subsurface reflections were recorded in Lubec Narrows, Area F. In spite of this, a rather extensive area of overburden has been outlined to the south of Mulholland Point, where the geologic section indicates bedrock extending across the narrows. The basis for this interpretation is as follows:

1. The north ends of all three profiles as they extend into Johnson Bay indicate sedimentary overburden (F1 between fiducials 1 and 2, F2 between fiducials 19 and 20 and F3 at fiducial 22). Bedrock appears to come to the surface at these locations.

2. Core #106-D indicates some 79 feet of clays, sands, boulders and gravels toward the south end of Lubec Narrows. The only bedrock reflection in this area is encountered at fiducial 25 on line F3 and is only classified as probable.

3. Rock outcrops are indicated on the U.S.G.S. topographic map at the low tide level along much of Lubec Narrows. The outcrops shown at Lubec and Mulholland Light support the extension of the bedrock across the narrows at this location.

AREA G. Fairly well-defined areas of overburden were outlined in Area G on each side of Pope's Folly Island. In addition to the outcrops of bedrock at either end of the area and around Pope's Folly Island, an interesting outcrop appears to the south of core 115-D. This shows on G1 at fiducial 7 and G2 near fiducial 7. This bedrock ridge is covered by 25 feet of overburden at line G3, but a side reflection from this outcrop to the south can also be seen on the record.

On line G3 at fiducial 14 an interface appears which correlates well with the clay-sand interface indicated in core 115-D at a depth of 28 feet below the bottom.

AREA H. Letite Passage is the main northmost entrance to Passamaquoddy Bay, where the tidal currents run more swiftly than in any other area surveyed. A narrow, deep channel was indicated with an unusually rough topography. Some small pockets of overburden were found on lines 2 and 18. The absence of sub-bottom reflections and the rough topography indicate a rocky bottom. Seven feet of gravel and cobbles are found at core 201-D. This thin veneer of sediments may be found in some areas, but is sometimes not recorded due to the width of the bottom reflection. Line H17 in figure 2 is typical of the records obtained in area H.

AREA J. Area J lies between Duck Point and West Quoddy Head. It is an area of good reflections with penetrations of almost 100 feet. Reflections from bedrock at depths of more than 100 feet were recorded with a probable reflection from a depth of 125 feet.

Rocks and shoals plotted on the U.S.G.S. topographic quadrangle, Lubec, Me., were used as an aid in drawing of contours in the shallow areas between ends of survey lines and shore.

Very good intermediate reflections were recorded on lines J6 through J9. These were probably due to variations in the characteristics of the clay bed encountered in core No. 107-D from near the surface to about 44 feet.

AREA K. This is a small shallow area directly to the south of Mathews Island. Beneath the rather smooth sedimentary bottom is found a rough bedrock surface. As much as 55 feet of sediments were encountered with good bedrock reflections throughout the area. Some intermediate reflections can be seen near the north-west corner. No geologic section was constructed for this area.

AREA L. This area consisted of a single profile through the Little Letite Passage just south of MacMaster Island. The very rough bottom indicates a rocky nature. A few sub-bottom reflections were recorded of apparently softer sediments lying in low spots where currents cannot reach. These were between fiducials 2 and 3, and between fiducials 5 and 6 on line L1. More overburden was indicated past the east end of the profile.

GEOLOGICAL CROSS SECTIONS

Geological cross sections were made through areas of greatest interest as indicated by the Corps of Engineers.

The depths to the bedrock and the bottom were plotted from the contour maps. The core information was used since most of the cores are located very close to the sections. The certain, probable, and speculative features shown on the bedrock profiles are also carried through in the intermediate reflecting beds.

CONCLUSIONS AND RECOMMENDATIONS

1) In spite of unfavorable natural operating conditions of current and tide, the physical guidance of the survey boat along the predetermined course lines was good.

2) The quality of the Marine Sonoprobe records would have been improved, and probably more sub-bottom information would have been obtained, had currents not been so strong, necessitating high boat speeds and a higher-than-normal noise from boat operation.

3) The Electro-Fix positioning system proved eminently satisfactory and accurate and the automatic position plotter enabled running of lines which otherwise would have required survey and establishment of hundreds of navigational ranges.

4) The prime object of the survey was to locate and define areas of low-density, compressible overburden, in order to determine the best crossings for rock dams. This type of overburden is particularly easily defined by the Marine Sonoprobe, and hence, the surveys are regarded as successful.

5) The surveys were not particularly successful in defining the areas of heavy gravel, and particularly so in the bottoms of the deep tidal guts, where the geometry is not favorable for acoustic methods. Since such varieties of overburden are not particularly capable of compaction, and tend to act much the same as bedrock, this lack of definition does not appear too important.

6) The technique of photographing the Marine Sonoprobe oscilloscope at the fiducials was not as helpful as had been foreseen, since, in the various survey areas, both bottom topography and sub-surface geology are changing so fast that observations of reflection quality of interfaces at horizontal intervals of 350 feet cannot be correlated with each other. This technique should have worked very well in the area of

Passamaquoddy Bay proper, where both topography and geology change only gradually with distance, and should be applied in similar areas.

7) The profile separation of 300 feet appears to have been quite suitable, on the average, for mapping the survey areas; in certain areas, however, a closer separation could have been asked for somewhat more accurate portrayal of the topography.

8) The data and maps have not been corrected quantitatively for "slant distance" effects, i.e., the fact that the depths indicated by the Marine Sonoprobe (except in areas of flat bottom) do not represent the true depths vertically below the boat, but the depths to the nearest reflecting surface within an angle of perhaps 15° from the vertical. Procedures for such correction are not established; indeed they are said by authorities to be impractical.

9) In the event that more detailed survey should be considered in the future in either these or other similar areas, it is recommended that the following be considered.

   a) Closer spacing of profiles.

   b) Establishing another set of lines parallel to the bottom topography.

   c) Running of longer lines, for geological background information.

   d) Provisions in the contract which would favor surveying only at times of best weather conditions.

10) All through our efforts at Eastport the cooperation of the Corps of Engineers and the people of Eastport, especially our local employees, was splendid and most appreciated.

Respectfully submitted,

FAIRCHILD AERIAL SURVEYS, INC.

Allen Fleming
Geophysicist

APPROVED:

F. W. Hinrichs
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TABLE I

GEOGRAPHIC COORDINATES OF BEACON STATIONS

	STATION	LATITUDE	LONGITUDE
1.	Bull Rear Range (1957)	44-56-56.649	66-55-34.591
2.	Chocolate (CHS 1948)	44-56-52.742	66-58-14.518
3.	Indian Point (1957)	44-56-24.390	66-58-10.334°
4.	Cable (1957)	44-55-30.230	66-58-34.460
5.	Shack (1957)	44-56-01.746	66-56-22.116°°
6.	RM-15	44-54-12.214	66-57-30.437
7.	Eastport (RM)	44-54-47.966	66-59-36.510
8.	Hibernia	44-57-21.074	66-57-54.517°°°
9.	MOWATT	44-59-58.376	66-54-29.291
10.	Kendall Two	44-55-57.506	67-00-56.464
11.	Cummings	44-56-52.680	67-00-03.835
12.	Deer Island (RM)	44-55-36.228	66-59-12.436
13.	Friar-South (1955)	44-52-28.804	66-58-25.127
14.	RM-33	44-51-37.097	66-58-44.545
15.	RM-43	44-49-52.916	66-59-28.064
16.	Quoddy	44-48-51.161	66-57-48.388
17.	Quoddy No. 2	44-53-30.034	66-59-48.353
18.	Mascabin Lighthouse	45-02-19.309	66-53-32.728
19.	Mathews (1863)	45-03-44.702	66-54-39.733
20.	Ledge (1951)	45-03-08.023	66-55-32.457
21.	New (approx.)	45-02-07.95	66-56-16.44
22.	James (approx.)	45-02-05.75	66-55-37.11
23.	Cove	44-54-06.058	67-03-29.964
24.	Spectacle	44-55-13.335	67-02-22.717
25.	Mulholland Point	44-51-46.783	66-58-48.589

In 3 cases, the shore stations were offset from the control stations by distances shown below:

° Indian Point offset 62'3" in a direction 215° from magnetic North.

°° Shack offset 24'6" in a direction 170° from magnetic North.

°°° Hibernia offset 14'3" in a direction 21° from magnetic North.

TABLE II

MORAN BEACON STATIONS CONTROLLING EACH AREA

AREA	A	(6)° RM-15 (7) Eastport (RM)
	B	(6) RM-15 (7) Eastport (RM)
	C	(6) RM-15 (7) Eastport (RM) South portion
		(3) Indian Point (1957) (4) Cable (1957) West half
		(2) Chocolate (CHS 1948) (12) Deer Island (RM) East half
	D	(8) Hibernia (1) Bullrear Range (1957) South Central portion
		(3) Indian Point (1957) (5) Shack (1957) North Central portion
		(6) RM-15 (5) Shack (1957) South portion
		(9) Mowatt (3) Indian Point (1957) North portion
	E	(1) Eastport (RM) (10) Kendall Two Deer Island Portion
		(11) Cummings (12) Deer Island (RM) Moose Island portion
	F	<u>Flag system by Corps of Engineers</u>
		(25) Mulholland Point (14) RM-33
	G	(14) RM-33 (13) Friar South (1955)
	H	(19) Mathews (1863) (20) Ledge (1951)
	K	<u>Flag system by Corps of Engineers</u>
		(23) Cove (24) Spectacle
	L	<u>Flag system by Corps of Engineers</u>
		(21) New (approx) (22) James

° Numbers in parenthesis ( ) refer to station number as shown on figure 4.

TABLE III

LENGTHS OF SURVEY LINES BY AREA

AREA	FEET	MILES
A	45,790	8.67
B	44,940	8.51
C	56,360	10.67
D	202,340	38.32
E	26,950	5.04
F	7,320	1.32
G	9,700	1.84
H	59,830	11.33
J	5,760	1.09
K	40,480	7.67
L	10,830	2.05
	519,090	96.58